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The external effects of inner-city shopping centers: Evidence from the Netherlands

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Abstract

Shopping center redevelopment is inevitable to remain attractive for consumers. In this paper, we investigate the external effects of shopping center redevelopment on nearby residential property prices. Using a difference-in-difference empirical framework, we find the redevelopment has positive external effects on nearby property prices. We find the price of a property located next to a redeveloped shopping center increases by 1.43% on average just after redevelopment. Our results indicate that these positive external effects wear off rather rapidly across space and over time. This suggests that shopping center redevelopment plays a substantial, but limited, role in combating neighborhood deprivation.

KEYWORDS

difference-in-difference, external effects, redevelopment, shopping centers, urban revitalization

JEL CLASSIFICATION

C21; D62; R0

1 | INTRODUCTION

In the 20th century, shopping centers have become an established fact in modern urbanized economies.[1] Many of these shopping centers are developed in residential neighborhoods. These shopping centers are important neighborhood amenities providing goods, services and, increasingly, shopping experience to consumers.

[1]Shopping centers are those "commercial outlets which have been designed, planned, developed, and managed as one single unit," and are to be distinguished from shopping districts in terms of their single vis-a-vis multiple ownership and management control. Shopping centers can be located inside shopping districts. Unlike in the United States, many shopping centers in Europe are located in urbanized and residential areas.

For a shopping center to remain a community center of the neighborhood, a trend toward more extensive and more frequent redevelopment has been observed (Gibbs, 2012).[2] Shopping centers wear and tear off both physically, functionally, and economically, such that "malls built ten years ago are considered mature, those completed fifteen years ago being old, and malls completed twenty years ago being ancient" (Lord, 1985, p. 226). Online shopping has not curbed this trend. On the contrary, it has intensified the need for redevelopment to prevent dead shopping centers.

Redevelopment of a shopping center is, like any urban revitalization project, about internalizing externalities. Owners of shopping centers may be inclined to redevelop outdated shopping centers according to the most recent shopping trends and consumers' preferences only when private costs are fully covered (Brueckner, 1980; Brueckner & Rosenthal, 2009; Munneke, 1996; Rosenthal & Helsley, 1994). Postponing redevelopment and major maintenance leads to outdated and physically decayed shopping centers (Lord, 1985). As a result, retail vacancy in the shopping center rises and the net rental income of the shopping center declines. To maintain their market position, redevelopment of existing shopping centers seems inevitable (Sternlieb & Hughes, 1981). The redevelopment also affects the attractiveness of the surrounding neighborhood. After redevelopment, on one hand, residents in the neighborhood can enjoy the convenience brought by a renewed and trendy shopping center; on the other hand, some inconvenience caused by the shopping center, such as noise and traffic congestion, can be relieved. As a result, housing demand in neighborhoods near the redeveloped shopping center is likely to rise and, consequently, the transaction price of nearby residential properties will increase. Because of these external effects, redevelopment is not only of economic interest to shopping center owners, but also to local policy makers.

It is often assumed by policy makers that redevelopment is a tool to combat neighborhood deprivation. Policy makers who wish to revitalize neighborhoods do include social cost considerations and sometimes provide public finance in funding alterations to access and parking, or to public space to let a property owner redevelop their property (Ahlfeldt, Maennig, & Richter, 2016). A broad set of literature finds evidence for positive external effects from such place-based investments, such as brownfields (Kiel & Zabel, 2001), cultural heritage (Been, Ellen, Gedal, Glaeser, & McCabe, 2016; Koster & Rouwendal, 2017), industrial heritage (Van Duijn, Rouwendal, & Boersema, 2016), local parks (Livy & Klaiber, 2016), and subsidized housing (Koster & Van Ommeren, 2019; Schwartz, Ellen, Voicu, & Schill, 2006). These empirical studies suggest that property prices tend to be anywhere between 0% and 17% higher in neighborhoods after these investments. However, an important difference is that for most of these studies the decision maker is the (local) government whereas in our paper the decision maker is the owner of a shopping center. The aim of our paper is to explore whether shopping center redevelopment can combat neighborhood deprivation by investigating the external effects of shopping center redevelopment on nearby residential property prices.

We combine residential property transaction data between 1990 and 2014 with data on the location of shopping centers in the Netherlands, the timing of the shopping center redevelopment and other shopping center characteristics. In total, we examine 273 redeveloped shopping centers between 1992 and 2010 to elicit information on the external effects of shopping center redevelopment on surrounding residential property prices. We use a difference-in-difference approach to control for unobserved heterogeneity. Especially, the external effects associated with shopping centers are dynamic in nature. Properties located closer to a redeveloped shopping center are expected to experience higher external effects. Because of the deterioration of shopping centers, the external effects of redevelopment should not persist but decrease over time. Therefore, we also consider spatial and temporal dimensions of the external effects in our empirical analysis.

[2]Redevelopment refers to any revision of the built environment, and synonymous for revitalization, modernization, regeneration, renewal, and urban transformation. We use these terms interchangeably. In this paper, redevelopment of existing shopping centers refers to any major revision of the exterior or interior that "implies physical changes" (Lord, 1985, p. 227). Redevelopment includes a variety of actions, such as (a) expansions or reductions in the floor space of the shopping center, (b) the uplifting and enclosure of previously open shopping areas, and (c) refitting of multiple individual outlets.

The contribution of our study is threefold. First, we examine redevelopment for inner-city shopping centers in the Netherlands. The literature on the impact of shopping center redevelopment is rather absent. One of the reasons is that detailed information on shopping centers and associated redevelopment is often unavailable. Existing studies on retail examine the openings of new stores (Neumark, Zhang, & Ciccarella, 2008; Pope & Pope, 2015; Zhou & Clapp, 2015). We focus on the redevelopment of existing shopping centers. Second, we provide new insights into the external effects of shopping centers. Based on a comparison of residential property prices before and after redevelopment using a difference-in-difference approach, we examine the external effects of shopping centers on local housing markets. Third, we provide evidence of how these external effects evolve across space and over time. We incorporate spatial and temporal (interaction) variables to capture the dynamics of external effects, allowing for spatial and temporal changes in the external effects after redevelopment. A similar approach is used in Schwartz et al. (2006), Van Duijn et al. (2016), and Been et al. (2016). Our findings indicate that, before redevelopment, residential properties located within 1,000 m of shopping centers sell for less than comparable properties located further away from shopping centers. After redevelopment, nearby property prices increase because of the positive external effects caused by the redevelopment. These positive effects wear off across space and over time. The increase of property price caused by the redevelopment vanishes within a few years.

The remainder of this paper is organized as follows. Section 2 provides some theoretical background on the redevelopment of shopping centers, the timing of the redevelopment decision, and the associated external effects. Section 3 introduces the empirical methodology used in our analysis. The data and descriptive statistics are presented in Section 4. Section 5 reports and discusses our main results. In Section 6, we propose various sensitivity analyses. Section 7 concludes.

2 | THE REDEVELOPMENT OF SHOPPING CENTERS

We consider a housing market (residential neighborhood) where a shopping center is located. The shopping center provides residents living in the neighborhood with the convenience of shopping and easy access to entertainment which increases the attractiveness of the neighborhood (Bloch, Ridgway, & Dawson, 1994; Koster & Rouwendal, 2012; Kuang, 2017; Rosiers, Lagana, Théeriault, & Beaudoin, 1996; Shields, 1995). In contrast, the shopping center may also cause inconvenience (e.g., air pollution, crime, noise, and traffic congestion) which decreases the attractiveness of the neighborhood (Hughes & Sirmans, 1992; Ihlanfeldt & Mayock, 2010; Kahn & Schwartz, 2008; Lens & Meltzer, 2016; Pope & Pope, 2012; Smith, Poulos, & Kim, 2002; Swoboda, Nega, & Timm, 2015). The local housing market surrounding the shopping center may experience higher demand for housing if the convenience outweighs the inconvenience. Most of the existing studies argue that the presence of a shopping center is reflected in higher residential property prices in the neighborhood (Pope & Pope, 2015; Rosiers et al., 1996; Sirpal, 1994).

However, shopping centers deteriorate physically, functionally, and economically (e.g., facilities may be broken, decorations may fade, consumer demand changes, the entire design may become outdated, and so on) (Bokhari & Geltner, 2016; Clapp & Salavei, 2010; Williams, 1997). Compared to housing, shopping centers deteriorate much faster. A shopping center is considered to be mature after 10 years and ancient after 20 years (Lord, 1985). With the deterioration, retail vacancy in the shopping center starts to rise and the net rental income of the shopping center consequently decreases (Lord, 1985).[3] Meanwhile, the inconvenience may become worse and worse (e.g., crime rate may soar and traffic congestion may worsen). The decision on what to do with the deterioration is taken by the shopping center owner who wants to maximize lifetime profits. In every period, a shopping center owner can decide to leave the shopping center as it is, sell the shopping center or redevelop the shopping center.

Redeveloping the shopping center according to the most recent shopping trends and consumers' preferences is attractive if the expected change in net rental income is higher than the private costs of redevelopment. The timing of

[3]A shopping center owner may directly be affected if the tenants' rent is linked to the turnover. Lord (1985) discusses that redevelopment efforts—in some cases—have been directly stimulated by the loss of an anchor tenant.

redevelopment depends on the marginal cost of foregone rental income and the expected marginal benefits of redevelopment (Wong & Norman, 1994). Once the shopping center is redeveloped—updated and adjusted to meet customers' demand—the benefits of the shopping center are restored and likewise the attractiveness of the neighborhood are expected to increase (Chebat, Michon, Haj-Salem, & Oliveira, 2014). Any inconvenience caused by the deterioration of shopping centers may also be alleviated. For example, traffic congestion could be solved if the roads around shopping centers are restructured and if more parking space is provided. After redevelopment, it is expected that the demand for housing on the local housing market will increase. This implies that residential properties in close proximity to the redeveloped shopping center are expected to sell at higher prices compared to similar properties which are not affected by the shopping center redevelopment. This, in theory, advocates that shopping center redevelopment can be used as a tool to combat neighborhood deprivation. However, over time, the shopping center starts to deteriorate again and, as a consequence, the positive external effects of redevelopment on property prices are expected to decrease.

3 | EMPIRICAL METHODOLOGY

Our goal is to identify the external effects of shopping centers by considering residential property prices after the redevelopment. External effects are not directly observed so they must be identified in an indirect way. We use residential property prices in the proximity of redeveloped shopping centers for that purpose. We propose to extend the model to cover estimates for heterogeneity in external effects across space and over time. Properties are differentiated by proximity to the redeveloped shopping center and the timing of the sale. This faces us with the challenge to define areas which received external effects (target areas) and which do not (control areas), and to disentangle the external effect of redeveloped shopping centers from other influences that have an impact on residential property prices. We, therefore, pay careful attention to defining target and control areas. We deal with these issues later in this section.

To identify the external effects of redeveloped shopping centers on property prices, we estimate a difference-in-difference hedonic price model to capture the price change after redevelopment in predefined target and control areas. Specifically, we estimate the following equation:

$$\begin{aligned}\log(P_{ijt}) = {} & \alpha + \beta_1 \mathrm{Target}_i + \beta_2 \mathrm{Target}_i \times \mathrm{Distance}_i + \beta_3 \mathrm{Target}_i \times \mathrm{Trend}_t + \beta_4 \mathrm{Target}_i \\ & \times \mathrm{Trend}_t \times \mathrm{Distance}_i + \theta_1 \mathrm{Target}_i \times \mathrm{Post}_t + \theta_2 \mathrm{Target}_i \times \mathrm{Post}_t \times \mathrm{Distance}_i \\ & + \theta_3 \mathrm{Target}_i \times \mathrm{Post}_t \times \mathrm{Trend}_t + \theta_4 \mathrm{Target}_i \times \mathrm{Post}_t \times \mathrm{Trend}_t \times \mathrm{Distance}_i \\ & + \sum_{k=1}^{K} \phi_k X_{kit} + \gamma_t + \mu_j + \varepsilon_{it},\end{aligned} \tag{1}$$

where $\log(P_{ijt})$ is the log of the price of property i in a (small) geographical area j and in sale year t; Target_i is a dummy variable indicating whether property i is located in the target area or not; $\mathrm{Distance}_i$ is the distance between property i and its nearest redeveloped shopping center; Trend_t is the difference between the year of sale t of property i and the year of completion of the nearest redeveloped shopping center; Post_t is a dummy variable which reflects whether property i is sold after the redevelopment or not (more information about Target_i, $\mathrm{Distance}_i$, Trend_t, and Post_t are described below); X_{kit} represents a set of control variables ($k = 1, 2, \ldots, K$) which include structural characteristics of property i in year t, shopping center characteristics of the nearest redeveloped shopping center and characteristics of the neighborhood where the property i is in year t; γ_t and μ_j are separately year of sale and (small-scale) area fixed effects; ε_{it} is an idiosyncratic error term. The coefficients to be estimated are α, β_{1-4}, θ_{1-4}, ϕ_k, γ_t, and μ_j.

Our difference-in-difference approach includes two key variables, Target_i and $\mathrm{Target}_i \times \mathrm{Post}_t$. We use these variables to investigate the external housing market effects of the shopping center redevelopment. Target_i equals one if property i is in the target area, zero otherwise. It captures the difference in residential property prices between properties located in the target area and those in the control area before the redevelopment of shopping centers. $\mathrm{Target}_i \times \mathrm{Post}_t$ is the main variable of interest. It equals one if property i is located in the target area and is sold after the redevelopment, zero otherwise. The coefficient of this variable measures the external effect of the redevelopment of shopping centers on residential property prices in the target area. In our empirical strategy, we initially set our target area to be within 1,000 m to the nearest redeveloped shopping center, while the control area is between 1,000 and 2,000 m.[4] To use the outer rings as control areas is not unusual in the literature (see, e.g., Ahlfeldt et al., 2016; Helmers & Overman, 2017; Schwartz et al., 2006; Van Duijn et al., 2016). In our sensitivity analyses, we check the robustness of our coefficients by changing the control area using propensity score matching.

We interact Target_i and $\text{Target}_i \times \text{Post}_t$ with Trend_t. $\text{Target}_i \times \text{Trend}_t$ is included to identify the temporal heterogeneity of property price difference between target and control areas before redevelopment. It equals property *i*'s year of sale minus the year of redevelopment of the nearest redeveloped shopping center, given that property *i* is sold before the redevelopment and located in the target area. The coefficient can be interpreted as how the property price difference between the target and control area before redevelopment has changed over time. Similarly, $\text{Target}_i \times \text{Post}_t \times \text{Trend}_t$ equals property *i*'s year of sale minus the year of redevelopment if property *i* is located in the target area and is sold after redevelopment. Like $\text{Target}_i \times \text{Trend}_t$, it suggests how the external effects of the redevelopment of shopping centers on property prices vary over time.

All these variables are interacted with Distance_i, which allows us to observe how these effects vary with distance.[5] The distance variable is measured by the Euclidean distance between property *i* and the polygon's edge of the nearest shopping center, using Geographic Information System (GIS) techniques.[6] The polygons for shopping centers are drawn in GIS based on their actual locations, shapes, and sizes, and they reduce measurement error in the distance from properties to shopping centers. This holds particularly for large shopping centers.[7]

To capture the external effects—and its dynamics—that shopping centers have on residential property prices is challenging because the selection of redeveloped shopping centers may not be random. Although this problem would be more severe if we focused on newly built shopping centers, it is possible that the decision and timing of redeveloping shopping centers depend on characteristics of properties and neighborhoods. If that were the case, we should be concerned that the external effects of redevelopment are actually reflecting unobserved property and neighborhood characteristics, rather than the external effects themselves. We do not expect such endogeneity issues because our methodology does not depend on the catchment area of the shopping center.[8] To probe more deeply into this, we check for nonrandom selection of redevelopment in a more formal way in Appendix B by estimating a logit model of redevelopment on neighborhood characteristics. We find—including many control variables—no significant effect of residential property prices on the redevelopment decision of shopping centers.

Next, we propose to run a number of sensitivity analyses to check the robustness of our proposed specification. First, we use alternative specifications to relax our assumptions of the fixed target area. The interaction of the key variables and the distance variables makes it possible to (easily) determine the range of the target area. The alternative specification checks whether our proposed target area is robust. Also, it checks for any nonlinear relationship of the external effects across space.

Second, we check the heterogeneity of the redevelopment external effects on property prices. There is a high variation in sizes of shopping centers. Large shopping centers are more inclined to have massive and distinguished redevelopment, such that the redevelopment of large shopping centers may have higher external effects compared with small shopping centers. To examine this, we separately estimate external effects for large and small shopping centers. We also test whether the external effects are heterogeneous between urban and rural areas. The convenience of

[4]This is our proposed radius based on previous literature and many of our own sensitivity checks.

[5]We have checked the nonlinearity of the effect of distance and time. The empirical results showed that the spatial and temporal change of the price effects is very similar to a linear functional form.

[6]We measure distance as Euclidean distance given the very local neighborhoods of within walking distance of our target areas.

[7]In Appendix A, we include an example of a redeveloped shopping center which is located in Amsterdam. By accounting for the shape and size of the shopping center, we minimize measurement error of our distance variable and we show how that affects the predefined target and control area.

[8]The definition of our predefined target area is not equal to the catchment area of a shopping center. Catchment areas of shopping centers are—using our own experiences and anecdotal evidence—much larger than our target areas. This implies that we only measure local price effects of redevelopment on nearby housing markets.

shopping centers and solving the inconvenience (such as traffic congestion) may be valued differently by urban residents. The perception of external effects may differ for properties in urban areas. Furthermore, we also investigate if the redevelopment of indoor and outdoor shopping centers may generate different external effects on property prices.

Third, we perform a repeat sales analysis to control for unobserved differences across properties and potential changes in the mix of residential properties that sell before and after the redevelopment of shopping centers. If there are relevant omitted property characteristics that are changed before or after the redevelopment of the shopping centers, there could be potential upward bias of the external effects in the hedonic analysis. Repeat sales methods only consider properties that are sold more than once during the observation period in the analysis. While this may yield a more selective sample compared to our proposed difference-in-difference hedonic analysis, it helps identifying whether unobserved property characteristics do play any role in our original estimates.

Finally, we focus on the definition of the control areas. Our proposed empirical methodology provides a simple way to determine the range of external effects of redevelopment across space, but identifying the "correct" control area is more controversial. Initially, we propose to use the outer ring—just outside the specified target area—as the control area. As an alternative, we propose to use the propensity score matching method to define control areas. For the difference-in-difference methodology, it is important that the target and control areas are identical, except for the event of redeveloping a shopping center. Matching estimators impute counterfactual observations by pairing properties in target areas with similar properties which are then defined as control areas.[9] The use of matching estimators is becoming more and more popular in the economic literature (e.g., Ahlfeldt et al., 2016; Koster & Van Ommeren, 2019; McMillen & McDonald, 2002; Muehlenbachs, Spiller, & Timmins, 2015; Van Duijn et al., 2016). It should, however, be noted that changing the control area has limited effect on one of our key variables, $Target_i \times Post_t$, as variation over space and time of the shopping center redevelopment occurs within the target area.[10]

4 | DATA

Our analysis combines data from multiple sources. First, we use residential property transactions in the Netherlands between 1990 and 2014 provided by the Dutch Association of Real Estate Agents (NVM), which covers around 70% of the total residential transactions in the Netherlands. Second, we use shopping center information provided by the Dutch Shopping Center Council (NRW). This data set contains detailed information of 989 shopping centers in the Netherlands that opened before 2011. Among these shopping centers, we observe 437 shopping centers which have been significantly redeveloped between 1979 and 2010.

From the shopping center data set, we selected the redeveloped shopping centers for further examination based on the following considerations. First, we excluded 13 shopping centers because they were redeveloped within 4 years after their opening.[11] These shopping centers are probably not redeveloped because of deterioration, which is different from the other redeveloped shopping centers and divergent from the focus of this paper. Then we selected shopping centers which have enough residential property transactions within the target and control areas. We exclude 116 shopping centers because we observe fewer than 30 property transactions either in the target (before and after redevelopment separately) or control area.[12] In addition, 14 shopping centers redeveloped before 1992 are excluded because for these shopping centers we do not have enough years of residential property transactions to measure trend effects before

[9]More information on the techniques involved in matching estimators can be found in Abadie and Imbens (2006, 2011).

[10]We thank an anonymous referee for this insightful comment.

[11]Redevelopment involves various decision processes and costs, which means that the timing of redevelopment cannot be too close to the opening or last redevelopment of the shopping center. Therefore, we believe these 13 shopping centers that are divergent from the usual redevelopment cycle are redeveloped because of other reasons but not deterioration.

[12]There are basically two situations why these shopping centers do not have enough property transactions around them. Most of these shopping centers are located in rural areas so that they do not have enough property transactions observed within 1,000 m of them, either before or after the redevelopment. There are also some dropped shopping centers that are situated near the edge of a relatively small residential area. Most of the property transactions happened in the target areas and thus we do not have enough property transactions in the control areas.

redevelopment. Furthermore, two shopping centers are excluded because they are located too close to the Dutch border, so that most of the target or control area around them is not located in the Netherlands. At last, we dropped 19 specialized shopping centers, including retail parks, factory outlet, and theme-oriented centers, considering they have different purposes and thus may cause different influences on nearby residential properties compared with other traditional shopping centers.[13] This results in 273 redeveloped shopping centers used in our analysis. Figure 1 presents the location of all redeveloped shopping centers in our data set. The triangles represent redeveloped shopping centers used in our analysis, while the crosses are those shopping centers which we dropped.

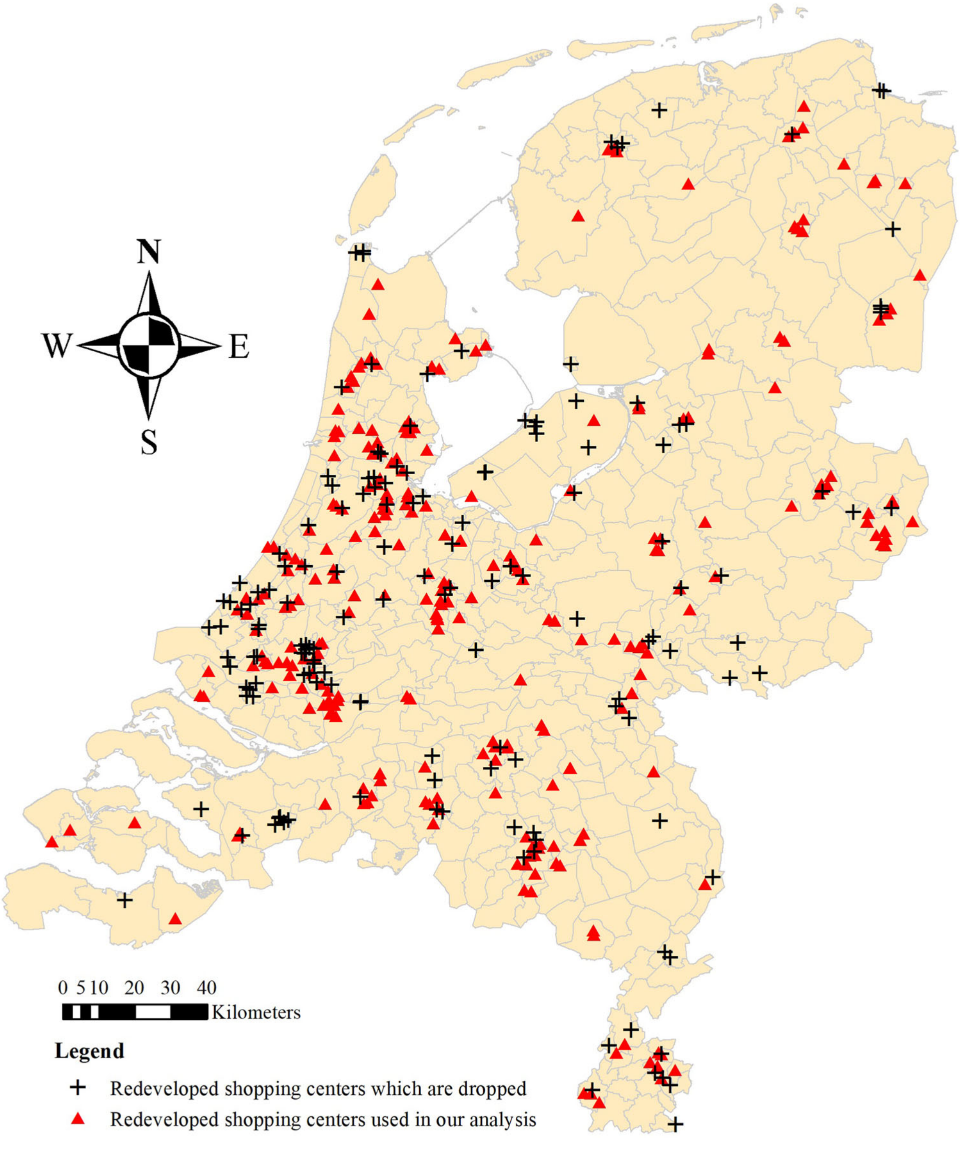

FIGURE 1 Location of redeveloped shopping centers. The triangles are those shopping centers used in our analysis, while the crosses represent those ones that are redeveloped but dropped out from our analysis [Color figure can be viewed at wileyonlinelibrary.com]

[13]According to the European Shopping Center Standard published by International Council of Shopping Centers (ICSC), shopping centers are grouped into two categories: traditional and specialized. Specialized shopping centers represent the ones built for a specific purpose, including retails parks, factory

TABLE 1 Summary statistics of redeveloped shopping centers

	Mean	*SD*	Median	Min	Max
Floor area (in 1,000 m^2)	9.342	11.021	5.7	2.5	90
Opening year	1976	10.666	1976	1885	2001
Renovation year	2000	4.622	2000	1992	2010
Number of outlets	35.703	34.785	24	3	257
Number of parking lots	332.238	557.980	200	0	6,400
Number of residential property transactions (<2,000 m)	3,146.462	2,206.889	2,717	202	13,132
Indoor (1 = yes)	0.447				
Park free (1 = yes)	0.722				
Number of observations	273				

Note: Our original data set contains 989 shopping centers all over the Netherlands, of which there are 437 shopping centers that are redeveloped. 13 shopping centers are dropped out because the timing of the redevelopment is very close to the opening of the shopping center. We drop another 116 redeveloped shopping centers because there are not enough transactions in the target area (before or after redevelopment) or in the control area. Fourteen shopping centers redeveloped before 1992 are excluded because we observe too few observations to measure trend effects before redevelopment. Also, another two shopping centers are excluded because they are too close to the Dutch border so that most of the area around them within 2,000 m is not in the Netherlands. At last, we dropped 19 specialized shopping centers because they are built for different purposes compared with other traditional ones. This results in 273 redeveloped shopping in our analysis.

Table 1 presents the summary statistics of the redeveloped shopping centers used in our analysis. As shown, our sample covers both relatively small shopping centers (2,500 m^2) and large ones (90,000 m^2). The average size of these shopping centers is 9,342 m^2. There are shopping centers in the data set which initially opened about 100 years ago, but there are also some newly built ones that are opened after 2000. All these shopping centers are redeveloped between 1992 and 2010, with a median redevelopment year of 2000. The average number of property transactions within 2,000 m of a redeveloped shopping center is 3,146. About 44.7% of these redeveloped shopping centers are enclosed (rather than open-air) and about 72.2% of them provide free parking.

The NVM data contain detailed information on the transactions of residential properties, including residential property price, exact street address, type of property, floor space, year built, number of rooms, and so on. We select those properties that are located within 2,000 m of each redeveloped shopping center. We exclude properties whose transaction price per m^2 is beyond the 1st and 99th percentiles in each transaction year. Besides, we also omit properties whose size is smaller than the 1st percentile or larger than 99th percentile of all the properties. Finally, there are 828,567 residential property transactions left in our sample.

Table 2 shows summary statistics of the residential property transactions. The transaction prices range from 25,185 to 1,200,000 euros, with an average of 185,810 euros. The average lot size of transacted properties is about 114 m^2. The lowest transaction price per m^2 is about 253 euros; this is because some property transactions in our data set occurred in the early 1990s and in rural areas. On the contrary, the highest price per m^2 which is about 4,667 euros reflects those properties located in central cities, such as Amsterdam. The average distance of each property to its nearest redeveloped shopping center is about 888 m, with a median around 826 m. Only a few properties in our data set are built after 2000 which is not surprising as newly built properties are often not recorded by the NVM and most redeveloped shopping centers in our sample are originally located within existing residential areas.

outlet centers, and theme-oriented centers. A traditional shopping center is the one with all purposes. For more detailed information, see https://www.icsc.org/uploads/research/general/euro_standard_only.pdf.

TABLE 2 Summary statistics of residential property transactions

	Mean	*SD*	Median	Min	Max
Structural characteristics					
Residential property price (in 1,000 euros)	185.810	101.804	165.630	25.185	1,200
Size (m^2)	114.381	35.465	112	45	260
Price per m^2	1,638.973	682.405	1,600	253.460	4,666.667
Number of rooms	4.279	1.230	4	1	10
Distance to the nearest redeveloped shopping center (m)	888.485	515.509	825.501	0	2,000
Apartment (1 = yes)	0.297				
Property type—town (1 = yes)	0.366				
Property type—corner (1 = yes)	0.146				
Property type—semidetached (1 = yes)	0.124				
Property type—detached (1 = yes)	0.067				
Balcony (1 = yes)	0.270				
Terrace (1 = yes)	0.057				
Parking (1 = yes)	0.278				
Well-maintained garden (1 = yes)	0.260				
Bad inside maintenance (1 = yes)	0.017				
Bad outside maintenance (1 = yes)	0.011				
Central heating (1 = yes)	0.904				
Monument (1 = yes)	0.004				
Building periods					
<1945 (1 = yes)	0.226				
1945–1960 (1 = yes)	0.066				
1961–1970 (1 = yes)	0.180				
1971–1980 (1 = yes)	0.188				
1981–1990 (1 = yes)	0.157				
1991–2000 (1 = yes)	0.123				
>2000 (1 = yes)	0.061				
Number of observations	828,567				

Note: In our sample, we only include residential properties that are located within 2,000 m of the redeveloped shopping centers and were sold between 1990 and 2014. Observations whose property price per square meter is smaller than 1st percentile or larger than 99th percentile (based on each year) are deleted. Furthermore, we dropped observations whose size is outside of the 1st and 99th percentiles.

Table 3 depicts the summary statistics of residential property transactions in our initially chosen target and control areas separately. There are more observations in the target area, and this is because usually the target area is located closer to the neighborhood center. The average residential property price and price per m^2 in the target area are smaller than those in the control area but the difference is not even a quarter of a standard deviation. If differences in property prices are mainly caused by the location of the property, it can be captured by small-scale location fixed effects.

One of the assumptions of the difference-in-difference methodology is that the development of the dependent variable—in our case, residential property prices—is identical between the target and control area before redevelopment. Because we observe many redeveloped shopping centers with different redevelopment timings, it is not easy to test this assumption. In Appendix C, we show figures of the development of average residential property prices and average residential property prices per m^2 of target and control areas before and after redevelopment. The trend in both target and control areas follow similar patterns, which gives us initial assurance that the difference-in-difference assumption is satisfied. To probe more deeply into our unconfoundedness assumption, in our sensitivity analysis we also consider different definitions of the control area using propensity score matching.

TABLE 3 Summary statistics of residential property transactions by target and control area

	Target area (0–1,000 m)					Control area (1,000–2,000 m)				
	Mean	*SD*	Median	Min	Max	Mean	*SD*	Median	Min	Max
Structural characteristics										
Residential property price (in 1,000 euros)	178.102	96.327	160	25.185	1,170	197.637	108.621	175	25.185	1,200
Size (m^2)	112.228	34.577	110	45	260	117.685	36.541	115	45	260
Price per m^2	1,604.993	658.861	1,570.777	253.460	4,649.123	1,691.118	713.896	1,652	252.481	4,650.538
Number of rooms	4.238	1.229	4	1	10	4.343	1.228	4	1	10
Distance to the nearest redeveloped shopping center (m)	534.521	264.569	537.705	0	999.996	1,431.675	280.758	1,406.570	1,000.003	2,000
Apartment (1 = yes)	0.318					0.264				
Property type—town (1 = yes)	0.369					0.361				
Property type—corner (1 = yes)	0.148					0.144				
Property type—semidetached (1 = yes)	0.108					0.149				
Property type—detached (1 = yes)	0.057					0.082				
Balcony (1 = yes)	0.285					0.247				
Terrace (1 = yes)	0.053					0.062				
Parking (1 = yes)	0.261					0.303				
Well-maintained garden (1 = yes)	0.243					0.286				
Bad inside maintenance (1 = yes)	0.017					0.017				
Bad outside maintenance (1 = yes)	0.011					0.011				
Central heating (1 = yes)	0.906					0.901				
Monument (1 = yes)	0.003					0.005				
Building periods										
<1945 (1 = yes)	0.204					0.259				
1945–1960 (1 = yes)	0.062					0.072				
1961–1970 (1 = yes)	0.221					0.117				
1971–1980 (1 = yes)	0.210					0.153				
1981–1990 (1 = yes)	0.163					0.148				
1991–2000 (1 = yes)	0.091					0.173				
>2000 (1 = yes)	0.049					0.079				
Number of observations	501,663					326,904				

5 | MAIN RESULTS

In this section, we report the regression results of the difference-in-difference hedonic price model. We investigate whether there are external effects of redeveloping shopping centers on nearby residential property prices and what the magnitudes of these external effects are across space and over time. We start by reporting the results of our preferred model following Equation (1). Initially the target area is within 1,000 m to the nearest redeveloped shopping center, while the control area is between 1,000 and 2,000 m. Table 4 reports the key coefficients and standard errors of various specifications where we consider 273 redeveloped shopping centers.[14]

Column (1) reports the results from a naive specification which only includes the key variables and their interactions, year of sale fixed effects and location fixed effects at the postcode (PC6) level.[15] The small-scale location fixed effects control for all time-invariant location characteristics. As shown in column (1), the coefficient on Target_i is negative and significant, suggesting that properties located just next to a redeveloped shopping center and sold just before the redevelopment ($\text{Distance}_i = 0$ and $\text{Trend}_t = 0$) sell for 11.8% ($= (\exp^{(-0.126)} - 1) \times 100$) less on average than properties located in the control area. This seems to suggest that just before redevelopment, shopping centers may be so outdated that they are a blister to nearby residential properties, although this effect may not be causal. The coefficient of $\text{Target}_i \times \text{Distance}_i$ is positive and significant, which means the price difference becomes smaller for properties located further from a redeveloped shopping center. The price difference disappears—on average—for properties located around 900 to 1,000 m from a shopping center. This supports our proposed radius of the target area. The coefficient of $\text{Target}_i \times \text{Trend}_t$ measures how the price difference before redevelopment between the target and control area varies over time. Its coefficient is negative and significant. This implies that, on average, price difference becomes greater over time—more than a quarter of a percent per year—until the moment of redevelopment. When it comes closer to the redevelopment, the price difference between the target and control area becomes broader. The positive coefficient of $\text{Target}_i \times \text{Trend}_t \times \text{Distance}_i$ shows that the trend effect before redevelopment changes with distance. For properties that are further away from a redeveloped shopping center, the price difference before redevelopment grows more slowly over time.

The coefficient on $\text{Target}_i \times \text{Post}_t$ captures the positive external effects of redevelopment for residential properties located just next to a redeveloped shopping center and sold just after the redevelopment ($\text{Distance}_i = 0$ and $\text{Trend}_t = 0$). The results in column (1) show that the redevelopment generates on average 1.23% increase in residential property prices when comparing those properties with properties in the control area. The positive coefficient decreases with distance, as suggested by the negative coefficient before $\text{Target}_i \times \text{Post}_t \times \text{Distance}_i$. However, this coefficient is not statistically significant. The negative coefficient of $\text{Target}_i \times \text{Post}_t \times \text{Trend}_t$ indicates that the external effects of redevelopment on property prices decrease over time. These results are in line with our expectations formulated in Section 2. The coefficient of $\text{Target}_i \times \text{Post}_t \times \text{Trend}_t \times \text{Distance}_i$ shows that positive external effects after redevelopment diminishes more quickly over time for properties that are closer to the shopping center.

In Column (2), we control for many property characteristics which are standard in hedonic price studies. As expected, coefficients of our key variables are sensitive when property characteristics are omitted. It is noteworthy that the price difference between properties in the target and control area becomes much smaller. For properties located next to a redeveloped shopping center and sold just before the redevelopment, the transaction price is about 3% lower compared with properties in the control area. Both interaction terms with distance become statistically insignificant, although they still have the expected sign. This means the price difference before redevelopment is indifferent to distance. Properties located closer to a redeveloped shopping center are not sold for less before redevelopment. The external effect of redevelopment increases to 1.37% for properties located next

[14]We use clustered standard errors at redeveloped shopping center level to control for spatial correlation. We also experimented with using standard errors clustered at neighborhood or postcode level. The results are really similar, and our main conclusion remains unchanged.

[15]In the Netherlands, a postcode (PC6) is a combination of four digits and two letters. One PC6 represents a street (on average, 15 properties).

TABLE 4 Difference-in-difference regression results

	(1)		(2)		(3)		(4)	
Sample	**<2,000 m**		**<2,000 m**		**<2,000 m**		**<2,000 m**	
Target area	**0–1,000 m**		**0–1,000 m**		**0–1,000 m**		**0–1,000 m**	
Control area	**1,000–2,000 m**		**1,000–2,000 m**		**1,000–2,000 m**		**1,000–2,000 m**	
Target	−0.126***	(0.0280)	−0.0300*	(0.0174)	−0.0247	(0.0187)	−0.00693	(0.00837)
Target × Distance	0.000123***	(2.73e−05)	2.79e−05	(1.74e−05)	2.26e−05	(1.87e−05)	6.60e−06	(9.12e−06)
Target × Trend	−0.00315**	(0.00149)	−0.00275*	(0.00146)	−0.00255*	(0.00131)	−0.000862	(0.00149)
Target × Trend × Distance	2.81e−06*	(1.59e−06)	2.52e−06	(1.58e−06)	2.29e−06	(1.50e−06)	7.18e−07	(1.77e−06)
Target × Post	0.0123**	(0.00609)	0.0136**	(0.00560)	0.0142***	(0.00548)	0.0113*	(0.00633)
Target × Post × Distance	−8.14e−06	(7.54e−06)	−1.09e−05*	(6.52e−06)	−1.18e−05*	(6.70e−06)	−7.57e−06	(7.85e−06)
Target × Post × Trend	−0.00458***	(0.000917)	−0.00396***	(0.000863)	−0.00347***	(0.000793)	−0.00161**	(0.000699)
Target × Post × Trend × Distance	4.65e−06***	(9.18e−07)	3.89e−06***	(8.53e−07)	3.59e−06***	(8.49e−07)	1.75e−06**	(8.36e−07)
Year fixed effects (24)	Yes		Yes		Yes		Yes	
Structural characteristics (14)	No		Yes		Yes		Yes	
Building periods (6)	No		Yes		Yes		Yes	
Shopping center characteristics (6)	No		No		Yes		Yes	
Shopping center type fixed effects (8)	No		No		Yes		Yes	
Neighborhood characteristics (5)	No		No		Yes		Yes	
PC6 fixed effects (91,502)	Yes		Yes		Yes		No	
PC4 fixed effects (1,281)	No		No		No		Yes	
Observations	828,567		828,567		828,567		828,567	
Adjusted R^2	0.882		0.941		0.942		0.901	

Note: Dependent variable is the log of residential property prices. We include 273 redeveloped shopping centers in our analysis. Standard errors clustered at redeveloped shopping center level and in parentheses. The other coefficients can be obtained from the authors.

*$p < .10$.

**$p < .05$.

***$p < .01$.

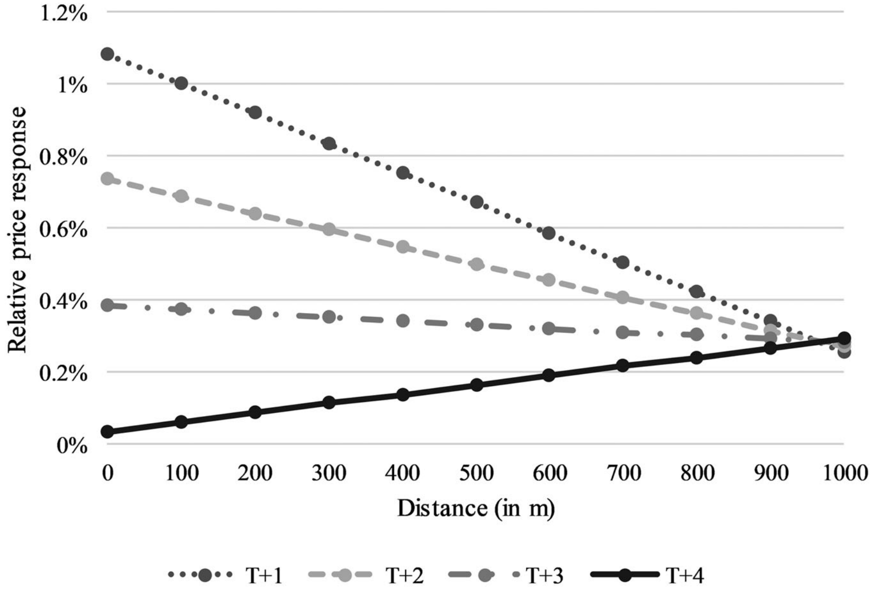

FIGURE 2 Change of the average external effects on property prices after redevelopment. T represents the redevelopment year of a shopping center. $T + l$ indicates l years after the redevelopment. The figure shows the change of external effects over space if properties are transacted at four different years after the redevelopment of shopping centers. The figures are calculated based on the results of column (3) of Table 4

to a redeveloped shopping center and sold just after the redevelopment. Different from column (1), the coefficient of $\text{Target}_i \times \text{Post}_t \times \text{Distance}_i$ is significant now, which means a property experiences larger external effects of the redevelopment if it is located closer to the shopping center.

Next, we include shopping center characteristics and neighborhood characteristics in column (3). The neighborhood characteristics are time-varying location variables that may have an influence on property prices. For the price difference between the target and control area before redevelopment, only the coefficient before $\text{Target}_i \times \text{Trend}_t$ remains significant at 10% level. This means there is no price difference between the target and control area just before redevelopment ($\text{Trend}_t = 0$). For external effects after redevelopment, the results are quite similar as previous estimates. For properties that are next to a redeveloped shopping center and sold just after redevelopment, the redevelopment increases their prices by about 1.43%, compared with properties that are not affected by the redevelopment of shopping centers. The other interaction terms also have intended signal and are significant, just as column (2).

Since column (3) is our complete and preferred specification of regression, we draw graphs using results from column (3) to illustrate in more detail about the spatial and temporal variations of the external effects after redevelopment. Figure 2 shows the dynamics of the positive external effect in space and time after redevelopment. The graph indicates that the positive external effects decrease over space and get close to zero around 1,000 m.[16] This implies that positive external effects on residential housing markets are, on average, rather local. Figure 2 also shows the positive external effects decline over time. The external effects decrease faster for properties closer to the redeveloped shopping center. Although in the 4th year after redevelopment the external effects remain positive, their values are relatively small. Figure 2 suggests that the external effects are rather local and wear off rather quickly across space and over time.[17]

[16]Figure 2 clearly shows that our proposed target area of a 1,000 m from shopping centers is reasonable and that no external effects seem to exist in areas further than 1,000 m of shopping centers.

[17]In Appendix D, we draw the external effects with their confidence intervals from the 1st to the 4th year after redevelopment separately.

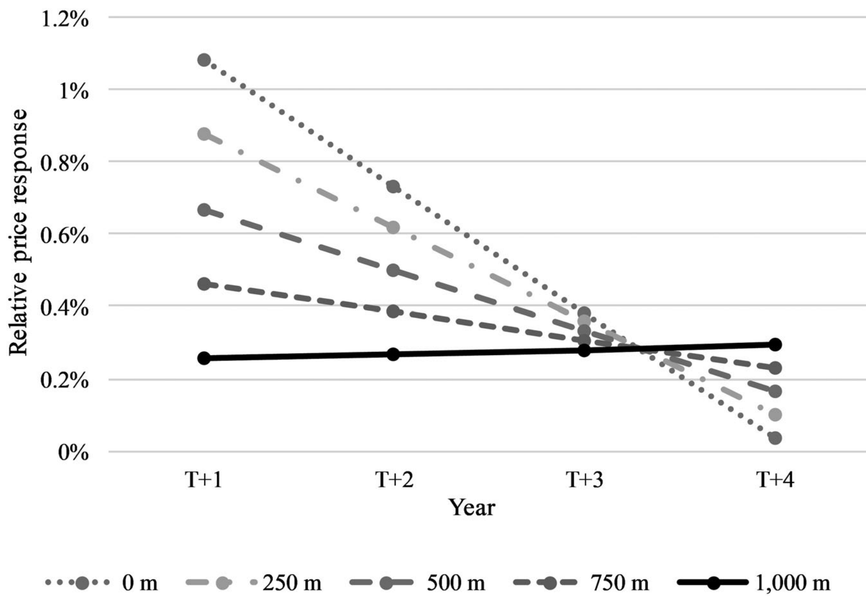

FIGURE 3 Another way to look at the change of the average external effects on property prices after redevelopment. *T* represents the redevelopment year of a shopping center. The figure shows the change of external effects over time for five different areas depending on the distance to the shopping center (in m). The figures are calculated based on the results of column (3) of Table 4

The dynamic pattern of the external effects of shopping center redevelopment is best revealed in Figure 3. We show that the positive external effects decrease rather quickly over time. The positive external effects become almost zero in the 4th year after redevelopment, for all properties with different distances. This again implies that redevelopment of shopping centers has a substantial impact on nearby residential housing markets just after redevelopment, but that shopping centers deteriorate—in the broadest sense of the word—rather quickly. The results in Table 4, which are supported by graphs in Figures 2 and 3, are consistent with our theoretical framework on the redevelopment external effects of shopping centers in Section 2.

From column (1)–(3), we use PC6 to control for unobserved time-invariant location characteristics. However, it is argued that PC6 can be too small-scaled and restrictive so that it may absorb part of the treatment effect (Abbott & Klaiber, 2011). As a result, we replace PC6 with PC4 in column (4) of Table 4. The insignificance of the first four coefficients shows that there is no price difference at all between the target and control area before redevelopment. The redevelopment increases the price by about 1.14% for properties located next to the redeveloped shopping center and sold just after the redevelopment, which is smaller compared with results using PC6. This external effect decreases over time and it decreases faster for properties located closer to the redeveloped shopping center. Our main conclusion remains the same.

6 | SENSITIVITY ANALYSES

In this section, we provide additional analyses to check the robustness of our regression results. First, we use an alternative specification of our preferred model to relax our assumptions of the fixed target area range. It also checks whether our proposed target area is reasonable and if the external effects across space are indeed as linear as suggested by our main results. Second, we test the heterogeneity of the external effects of redevelopment. Third, we perform a repeat sales analysis to control for unobserved differences across properties and potential changes in the mix of properties that sell before and after the redevelopment of shopping centers. Last, we focus on defining different control areas by using the propensity score matching method.

6.1 | Target area

In our preferred model, we set our sample to be within 2,000 m of a redeveloped shopping center. The target area is within 1,000 m of a redeveloped shopping center, while the control area is between 1,000 and 2,000 m. Using the specifications in Table 4 we tested the functional form of the distance decay of the external effects. The results indicate that the distance decay of the external effects shows most similarities with a linear functional form. However, the range of target area and the distance decay of the external effects may be different before and after the redevelopment. We propose to estimate a different specification to check the external effects of the redevelopment of shopping centers by relaxing the assumptions on linearity. To allow for different target ranges and nonlinear distance decay, we divide the sample area into different rings with a bandwidth of 250 m. Instead of using a continuous distance variable, we use dummy variables which indicate whether a property is within a distance range of a redeveloped shopping center. In other words, we create a set of dummy variables which represent 250 m rings (0–250, 250–500, 500–750, and 750–1,000 m) around a redeveloped shopping center and observe the average target effect of properties located within the same distance ring. We can combine the ring variables with the difference-in-difference method and generate this alternative specification of our preferred model. The alternative specification is as follows:

$$\begin{aligned}\log(P_{ijt}) = \alpha &+ \omega_{1z} R_z \text{Target}_i + \omega_{2z} R_z \text{Target}_i \times \text{Trend}_t + \omega_{3z} R_z \text{Target}_i \times \text{Post}_t \\ &+ \omega_{4z} R_z \text{Target}_i \times \text{Post}_t \times \text{Trend}_t + \phi X_{it} + \gamma_t + \mu_j + \varepsilon_{it},\end{aligned} \tag{2}$$

where R_z is a set of dummy variables for each 250 m ring. It equals one if a property is located within the corresponding 250 m ring z. We include the interaction terms of the ring dummy variables and key difference-in-difference variables. Like our preferred model in Table 4, we also include structural characteristics of properties, shopping centers and neighborhoods, year fixed effects, and location fixed effects as control variables. Therefore, the coefficients measure the heterogeneity of the average external effects for each distance ring. Moreover, it provides a sensitivity check on whether we correctly defined the predefined target area.

Table 5 shows the regression results of Equation (2). Column (1) excludes redeveloped shopping center characteristics and neighborhood characteristics, while column (2) includes them. The results of these two columns are quite similar. Both columns show that, for a property in the target area of a redeveloped shopping center and sold just before the redevelopment, its price is not significantly different with a similar property in the control area. Only properties located between 250 and 500 m of a redeveloped shopping center have a decreasing trend of price. It could well be that this drives our negative trend decay coefficient which is presented in Table 4.

The positive coefficients on our second key variable, $R_z \text{Target}_i \times \text{Post}_t$, show a linear distance decay effect in line with the results in Table 4. For a property within 250 m of a redeveloped shopping center and sold just after the redevelopment, its price increases by about 1.25%. The effect decreases to 0.95% at 250–500 m. The external effects decrease gradually over time and they decrease faster for properties within 250 m of a redeveloped shopping center than those at 250–500 m, as indicated by the negative and significant coefficients before $R_z \text{Target}_i \times \text{Post}_t \times \text{Trend}_t$. Most coefficients of the 500–750 and 750–1,000 m ring dummy variables are insignificant, which means properties in these rings are on average not affected by the external effects of shopping centers redevelopment. This suggests a smaller target area compared with our results in Table 4 and that we can reduce the radius of our target area to 500 m. We ran our baseline regressions again with target areas that are within 500 m of a redeveloped shopping center and control areas unchanged. The results are quite similar.

TABLE 5 Results of the alternative specification

	(1)		(2)	
Sample	**<2,000 m**		**<2,000 m**	
Target area	**0–1,000 m**		**0–1,000 m**	
Control area	**1,000–2,000 m**		**1,000–2,000 m**	
Target (0–250 m)	−0.00898	(0.00867)	−0.00752	(0.00894)
Target (250–500 m)	−0.00924	(0.00761)	−0.00847	(0.00747)
Target (500–750 m)	−0.00898	(0.00669)	−0.00864	(0.00656)
Target (750–1,000 m)	−0.00172	(0.00588)	−0.00135	(0.00565)
Target × Trend (0–250 m)	−0.00134	(0.00138)	−0.00127	(0.00124)
Target × Trend (250–500 m)	−0.00243**	(0.00110)	−0.00225**	(0.000966)
Target × Trend (500–750 m)	−0.00154	(0.00111)	−0.00144	(0.000983)
Target × Trend (750–1,000 m)	−4.07e−05	(0.00104)	−9.36e−05	(0.000951)
Target × Post (0–250 m)	0.0125**	(0.00573)	0.0124**	(0.00557)
Target × Post (250–500 m)	0.00872*	(0.00501)	0.00943*	(0.00488)
Target × Post (500–750 m)	0.00685	(0.00503)	0.00694	(0.00508)
Target × Post (750–1,000 m)	0.00463	(0.00578)	0.00424	(0.00573)
Target × Post × Trend (0–250 m)	−0.00332***	(0.000772)	−0.00290***	(0.000745)
Target × Post × Trend (250–500 m)	−0.00261***	(0.000717)	−0.00226***	(0.000626)
Target × Post × Trend (500–750 m)	−0.00138*	(0.000719)	−0.00100	(0.000663)
Target × Post × Trend (750–1,000 m)	−0.000672	(0.000615)	−0.000480	(0.000588)
Year fixed effects (24)	Yes		Yes	
Structural characteristics (14)	Yes		Yes	
Building periods (6)	Yes		Yes	
Shopping center characteristics (6)	No		Yes	
Shopping center type fixed effects (8)	No		Yes	
Neighborhood characteristics (5)	No		Yes	
PC6 fixed effects (91,502)	Yes		Yes	
Observations	828,567		828,567	
Adjusted R^2	0.941		0.942	

Note: Dependent variable is the log of residential property prices. Standard errors clustered at redeveloped shopping center level and in parentheses. The other coefficients can be obtained from the authors.
*$p < .10$.
**$p < .05$.
***$p < .01$.

6.2 | Heterogeneity

Our analysis above discusses the average external effect of redevelopment of shopping centers on property prices. However, there may exist heterogeneity in the external effects of redeveloped shopping centers. It is notable that there is a high variation in sizes of redeveloped shopping centers, ranging from 2,500 to 90,000 m^2. It is likely that larger redeveloped shopping centers will generate higher external effects on nearby property prices. This is because large shopping centers usually have broader catchment areas and their redevelopment can attract more attention from media and residents. Besides, the redevelopment of a large shopping center is more possible to have road restructured so that traffic congestion can be alleviated or even completely solved. We also investigate whether the redevelopment of shopping centers is heterogeneous for properties in the urban and rural areas.

Property prices in urban and rural areas are heterogenous (DiPasquale & Wheaton, 1996). Residents who choose to live in urban areas may value shopping centers differently from those in rural areas. Therefore, the perception of the external effects of redevelopment might differ between properties in urban and rural areas. In the end, we check the heterogeneity in external effects of redevelopment between indoor and outdoor shopping centers.

Table 6 reports our results of heterogeneity tests. First, column (1) to (2) show estimations for small and large shopping centers separately.[18] For properties next to small shopping centers, they are sold on average 3.1% less just before redevelopment, compared to similar properties in the control area. The price difference shrinks gradually with distance but broadens over time. However, there is no price difference at all between the target and control area around large shopping centers. The coefficients before $\text{Target}_i \times \text{Post}_t$ in column (1) and (2) show that the redevelopment of large shopping centers generate higher positive effects (2.47%) on nearby property prices than small shopping centers (1.35%), just as expected. The redevelopment external effects of both types of shopping centers show similar patterns in their changes over time, but clearly the effect of large shopping centers diminishes at a faster pace. Small shopping centers also have a negative and significant coefficient of $\text{Target}_i \times \text{Post}_t \times \text{Distance}_i$, which means the positive external effects of small shopping centers decrease with distance; however, this coefficient is not significant for large shopping centers.

Second, in column (3) and (4), we show regression results for properties in urban and rural areas separately.[19] For urban areas, there is no price difference between target and control area for properties sold just before the redevelopment. For properties in urban areas located next to the redevelopment shopping centers and sold just after the redevelopment, their prices increase by 1.44%, which is almost the same as our baseline results. The positive external effects caused by redevelopment decrease over time and space. However, the rural areas show quite different patterns. For rural area, the properties located next to the redeveloped shopping center sell on average 6.42% less than those in the control area just before redevelopment. The redevelopment of shopping centers has no external effects at all on property prices. This suggests residents living in rural areas may indeed have a different preference over shopping centers and may not be willing to pay higher prices for properties near a redeveloped shopping center. From a policy point of view, this implies to redevelop a shopping center in the urban area may bring more social benefits.

Third, another potential issue is that the redevelopment of indoor and outdoor shopping centers may generate different external effects on nearby property prices. This is because, for indoor shopping centers, all shopping activities happen within the enclosed "big box" and they are expected to have little influence on nearby property prices. For example, indoor shopping centers do not make noises as serious as outdoor shopping centers, so the redevelopment of indoor shopping centers may not have as high external effects as outdoor shopping centers. Columns (5) and (6) of Table 6 report the results for indoor and outdoor shopping centers separately. For both types of shopping centers, there is almost no price difference between target and control area before redevelopment. The redevelopment of outdoor shopping centers increases the price of properties by about 1.88% on average, for properties located next to a redeveloped shopping center and sold just after the redevelopment. The positive external effects decrease over time and space. On the contrary, the redevelopment of indoor shopping centers shows no external effects immediately, as indicated by the insignificant coefficient of $\text{Target}_i \times \text{Post}_t$. However, the negative coefficient before $\text{Target}_i \times \text{Post}_t \times \text{Trend}_t$ indicates the redevelopment of indoor shopping centers may decrease nearby property price gradually over time.

6.3 | Repeat sales analysis

Our main results are based on the difference-in-difference hedonic price model. It is well-known that hedonic price models are sensitive to omitted variables and failing to include important variables that influence property prices

[18]We followed ICSC's standard to identify shopping centers with fewer than 19,999 m^2 as small; the others as large. Most of our shopping centers are small shopping centers.

[19]Statistics Netherlands provides information about the urbanity level of each neighborhood from 1992 to 2010. Each neighborhood is given an urbanity Classes 1–5 based on its density of addresses. Class 1 represents very high urbanity, which represents more than 2,500 addresses per km^2. Class 5 represents no urbanity, which represents less than 500 addresses per km^2. We define the first two classes as urban areas and the others as rural areas.

TABLE 6 Heterogeneity

Group	(1) Small		(2) Large		(3) Urban		(4) Rural		(5) Indoor		(6) Outdoor	
Sample	<2,000 m		<2,000 m		<2,000 m		<2,000 m		<2,000 m		<2,000 m	
Target area	0–1,000 m		0–1,000 m		0–1,000 m		0–1,000 m		0–1,000 m		0–1,000 m	
Control area	1,000–2,000 m		1,000–2,000 m		1,000–2,000 m		1,000–2,000 m		1,000–2,000 m		1,000–2,000 m	
Target	−0.0302*	(0.0179)	0.00744	(0.0843)	0.00464	(0.0252)	−0.0622**	(0.0246)	−0.0269	(0.0270)	−0.0187	(0.0249)
Target × Distance	3.14e−05*	(1.76e−05)	−2.28e−05	(8.30e−05)	6.05e−06	(2.49e−05)	4.95e−05*	(2.63e−05)	2.54e−05	(2.76e−05)	1.56e−05	(2.44e−05)
Target × Trend	−0.00243*	(0.00139)	−0.00510	(0.00360)	−0.00341*	(0.00176)	−0.00311*	(0.00181)	−0.00405**	(0.00166)	−0.00111	(0.00191)
Target × Trend × Distance	2.57e−06	(1.57e−06)	3.64e−06	(4.02e−06)	3.23e−06*	(1.94e−06)	1.90e−06	(2.46e−06)	3.86e−06*	(1.98e−06)	8.55e−07	(2.18e−06)
Target × Post	0.0134**	(0.00587)	0.0244*	(0.0140)	0.0143**	(0.00719)	0.00913	(0.00917)	0.00662	(0.00762)	0.0186**	(0.00752)
Target × Post × Distance	−1.24e−05*	(7.22e−06)	−2.31e−05	(1.57e−05)	−1.73e−05*	(9.53e−06)	1.66e−06	(1.30e−05)	1.79e−06	(1.07e−05)	−2.00e−05**	(7.89e−06)
Target × Post × Trend	−0.00315***	(0.000829)	−0.00588***	(0.00199)	−0.00502***	(0.00106)	−0.00153	(0.00122)	−0.00302**	(0.00117)	−0.00406***	(0.00105)
Target × Post × Trend × Distance	3.08e−06***	(8.49e−07)	7.76e−06**	(3.37e−06)	4.48e−06***	(1.16e−06)	1.54e−06	(1.33e−06)	2.20e−06*	(1.32e−06)	4.83e−06***	(1.09e−06)
Year fixed effects	Yes		Yes		Yes		Yes		Yes		Yes	
Structural characteristics	Yes		Yes		Yes		Yes		Yes		Yes	
Building periods	Yes		Yes		Yes		Yes		Yes		Yes	
Shopping center characteristics	Yes		Yes		Yes		Yes		Yes		Yes	
Shopping center type fixed effects	Yes		Yes		Yes		Yes		Yes		Yes	
Neighborhood characteristics	Yes		Yes		Yes		Yes		Yes		Yes	
PC6 fixed effects	Yes		Yes		Yes		Yes		Yes		Yes	
Observations	734,345		94,222		503,633		324,934		371,929		456,638	
Adjusted R^2	0.942		0.944		0.939		0.950		0.942		0.943	

Note: Dependent variable is the log of residential property prices. Standard errors clustered at redeveloped shopping center level and in parentheses. The other coefficients can be obtained from the authors.

*$p < .10$.

**$p < .05$.

***$p < .01$.

TABLE 7 Results of repeat sales analysis

	(1)	
Sample	**<2,000 m**	
Target area	**0–1,000 m**	
Control area	**1,000–2,000 m**	
Transition: Before-Post	0.0188***	(0.00713)
Before-Post × Distance	1.75e−05**	(7.68e−06)
Target × Post × Trend	−0.00165***	(0.000538)
Target × Post × Trend × Distance	2.61e−06***	(7.52e−07)
Differenced year dummies	Yes	
Differenced structural characteristics	Yes	
Differenced neighborhood characteristics	Yes	
Building periods	No	
Shopping center characteristics	No	
Shopping center type fixed effects	No	
PC6 fixed effects	No	
Observations	233,710	
Adjusted R^2	0.688	

Note: Dependent variable is the difference between the log of residential property prices of the same residential property sold at different times. Standard errors clustered at redeveloped shopping center level and in parentheses. Building periods, shopping center characteristics, shopping center type, and PC6 fixed effects are time-invariant and therefore not estimated in this analysis. The other coefficients can be obtained from the authors.

*$p < .10$.

**$p < .05$.

***$p < .01$.

may cause biased coefficients. In our case, possible omitted variables are mainly unobserved property and neighborhood characteristics. In our data set we observe properties that are sold multiple times between 1990 and 2014. This enables us to use a repeat sales analysis to check the robustness of the results from our difference-in-difference hedonic price model. A repeat sales analysis controls for all time-invariant characteristics of properties and neighborhoods that may influence the property prices.[20] Following the repeat sales specifications used by Schwartz et al. (2006) and Van Duijn et al. (2016), we derive our repeat sales equation as follows:

$$\begin{aligned}\Delta_{t,s}\log(P_{ij}) = {}& \alpha\text{Before-Post}_i + \beta\text{Before-Post}_i \times \text{Distance}_i + \theta\text{Target}_i \times \text{Post}_t \times \text{Trend}_t \\ & + \delta\text{Target}_i \times \text{Post}_t \times \text{Distance}_i \times \text{Trend}_t + \phi\Delta_{t,s}X_i + \Delta_{t,s}\gamma + \Delta_{t,s}\varepsilon_{ij},\end{aligned} \tag{3}$$

where $\Delta_{t,s}$ represents the difference between two sales and Before-Post_i is a dummy variable indicating whether these two sales of a property in the target area happened before and after redevelopment separately.[21] Before-Post_i measures how the property price is going to change due to redevelopment if a property was sold before redevelopment and it was sold again after redevelopment. Similar to our preferred model, Before-Post_i is

[20]The repeat sales method has three shortcomings. First, it does not control for time-variant variables which may influence property prices. This may still lead to biased results. Second, there may exist a selection bias because it only includes property that are sold more than once. Third, repeat sales analysis always decreases the number of observations used in the analysis, which can lead to a less trustworthy estimation results.

[21]For a property located in the target area, $\text{Before-Post}_i = 1$ if this property was sold before the redevelopment and it was sold again after the redevelopment.

interacted with the distance variable to investigate how the effect is going to change with distance. All time-invariant variables are eliminated from Equation (3).

Table 7 reports the regression results of the repeat sales analysis. For a property that is located next to a redeveloped shopping center ($\text{Distance}_i = 0$) and sold twice (once before the redevelopment and once after the redevelopment), the impact of the redevelopment on residential property prices is 1.9%. This suggests the redevelopment of shopping centers has a positive external effect on nearby property prices. Compared to Table 4, the repeat sales analysis reports estimates with similar signs and magnitudes. These results suggest that there is little reason to be concerned about unobserved time-invariant differences of properties in the hedonic regressions discussed in Section 3.

6.4 | Propensity score matching

For the difference-in-difference methodology it is important that the target and control areas are comparable, especially if one wants to interpret the coefficient of the Target_i variable. This means, in our case, properties in the target and control area should be identical, except that one is within 1,000 m of a redeveloped shopping center and the other is not. In Appendix C, we show that the trend of residential property prices in target and control areas follow similar patterns both before and after redevelopment. This gives us initial assurance that the difference-in-difference assumption is satisfied. We observe 273 redeveloped shopping centers with each a different timing of redevelopment. One could argue that the trend of residential property prices does not reflect the assumption of identical patterns between the predefined target and control areas.

Another potential issue for our analysis is selection. In Section 4, we show that before redevelopment there exists a price difference between properties in the target and control areas. Except that this is affected by the redevelopment project, it is also possible there is some form of selection bias that the decision of redevelopment is dependent on the state of the neighborhood. Shopping centers in declining neighborhoods are targeted for redevelopment, so that they can revitalize the neighborhood. Another possibility is the location decision of developing shopping centers is historically determined by shopping center owners and policy makers, targeting at less attractive neighborhoods, because land costs are lower for owners therefore risk is lower and policy makers believe shopping centers make neighborhoods more attractive. In these cases, the target area is not assigned randomly and there can be a selection bias.

To solve for these concerns, we propose to use the propensity score matching method to match each target area to a similar control area. We calculate a propensity score for each neighborhood before the redevelopment based on a probit regression. We include many neighborhood characteristics in the probit regression, such as population density, average household size, average income per resident, percentage of immigrants and so on.

Table 8 shows the summary descriptive statistics of the neighborhood characteristics included in the probit regression. If two neighborhoods before the redevelopment have similar propensity scores, they are assumed to be identical to each other and have similar characteristics. We can find a matched control neighborhood for each target neighborhood by minimizing the difference in propensity scores. To ensure residential property prices in control neighborhoods are not affected by redeveloped shopping centers, we restrict all potential matched control neighborhoods to be located between 1,500 and 10,000 m from the redeveloped shopping centers. Our target area remains within 1,000 m of the redeveloped shopping centers.

Table 9 presents the regression results based on Equation (1). The only difference compared to the results in Table 4, our main results, is that our predefined target areas are now compared to residential properties in control areas defined by a propensity score matching method. Similar to Table 4, column (1) includes only our key difference-in-difference variables, year fixed effects, and location fixed effects. Column (2) adds property characteristics and column (3) adds shopping center and neighborhood characteristics. Column (3) is the focus of our analysis. Compared with column (3) of Table 4, the difference is that the coefficient before Target_i becomes positive but still insignificant. A property sold just before redevelopment and just next to the shopping center ($\text{Distance}_i = 0$ and $\text{Trend}_t = 0$) sells for no difference on average than similar properties in the matched control

TABLE 8 Comparison of neighborhood characteristics based on propensity score matching

	Target area		Control area	
	Mean	***SD***	**Mean**	***SD***
Average household size	2.176	0.776	2.160	0.795
Population density per km^2	4,280.884	3,951.096	4,261.920	4,249.824
Number of residents	2,356.248	2,741.534	2,258.966	2,595.133
Young people (<25 years) (%)	25.430	11.060	25.269	11.323
Elderly people (>65 years) (%)	13.827	11.325	13.429	10.753
Immigrants (%)	11.366	14.512	11.756	15.117
Neighborhood size (in hectare)	133.168	321.703	135.509	559.035
Average income per resident (in 1,000 euros)	2.199	4.799	2.089	4.776
Number of neighborhoods	3,164		3,164	

Note: The target area refers to neighborhoods within 1,000 m of a redeveloped shopping center. The control area refers to matched neighborhoods based on propensity score matching and located between 1,500 and 10,000 m of a redeveloped shopping center.

TABLE 9 Regressions results based on propensity score matching

	(1)		(2)		(3)	
Target area	**0–1,000 m**		**0–1,000 m**		**0–1,000 m**	
Control area	**Prop. score**		**Prop. score**		**Prop. score**	
Target	−0.0499	(0.102)	0.0727	(0.0686)	0.0876	(0.0695)
Target × Distance	0.000132***	(2.98e−05)	3.59e−05**	(1.79e−05)	3.18e−05*	(1.86e−05)
Target × Trend	−0.00355**	(0.00153)	−0.00288*	(0.00152)	−0.00260*	(0.00135)
Target × Trend × Distance	2.96e−06	(1.80e−06)	2.54e−06	(1.77e−06)	2.32e−06	(1.64e−06)
Target × Post	0.0120*	(0.00637)	0.0131**	(0.00591)	0.0137**	(0.00577)
Target × Post × Distance	−8.43e−06	(9.18e−06)	−1.04e−05	(8.21e−06)	−1.14e−05	(8.13e−06)
Target × Post × Trend	−0.00492***	(0.000991)	−0.00419***	(0.000913)	−0.00354***	(0.000837)
Target × Post × Trend × Distance	4.65e−06***	(1.17e−06)	3.87e−06***	(1.07e−06)	3.47e−06***	(1.05e−06)
Year fixed effects (24)	Yes		Yes		Yes	
Structural characteristics (14)	No		Yes		Yes	
Building periods (6)	No		Yes		Yes	
Shopping center characteristics (6)	No		No		Yes	
Shopping center type fixed effects (8)	No		No		Yes	
Neighborhood characteristics (5)	No		No		Yes	
PC6 fixed effects (110,399)	Yes		Yes		Yes	
Observations	966,145		966,145		966,145	
Adjusted R^2	0.874		0.939		0.939	

Note: Dependent variable is the log of residential property prices. The target group refers to properties located within 1,000 m of a redeveloped shopping center. The control group refers now to properties located within matched neighborhoods based on propensity score matching. Compared with Table 4, there are more observations in the control group. Standard errors clustered at PC4 level and in parentheses. The other coefficients can be obtained from the authors.
Abbreviation: Prop., propensity.

*$p < .10$.

**$p < .05$.

***$p < .01$.

area. The other coefficients are, as discussed in Section 3, quite similar to our preferred specification reported in Table 4. The coefficient before $Target_i \times Distance_i$ now is significant at 10% level. This indicates the price difference before redevelopment between target and control area indeed increases with the distance to the nearest redeveloped shopping center in the propensity score matching setting. The external effects after redevelopment is also very close to our results in column (3) of Table 4. The price of a property sold just after redevelopment and just next to the shopping center increases by 1.38%, which is really close to 1.43% in our baseline regression. Similar to Table 4, the external effect decreases over time and it decreases faster if the property is closer to the redeveloped shopping center.

7 | CONCLUSION

This paper investigates the external effects of inner-city shopping centers on local housing markets in the Netherlands by exploiting information on shopping center redevelopment. Shopping centers deteriorate over time and, therefore, shopping center owners redevelop their shopping centers to maximize lifetime profits. We argue that shopping center redevelopment has external effects on surrounding neighborhoods. We expect that local neighborhoods become more attractive after the redevelopment of shopping centers. If this is the case, shopping center redevelopment can be used as a tool to combat neighborhood deprivation.

To investigate the external effects of inner-city shopping centers, we use detailed information on 273 shopping centers that have been redeveloped between 1992 and 2010 in the Netherlands. We propose a difference-in-difference hedonic price model to compare residential property prices between target and control areas before and after redevelopment. We pay special attention to the heterogeneity of shopping center redevelopment external effects across space and over time. The redevelopment of shopping centers substantially increases local residential property prices. For a property located just next to a redeveloped shopping center and sold just after the redevelopment, its price increases by about 1.43% on average. However, the positive external effects after redevelopment become smaller with increasing distance for a given moment in time (until about 1,000 m) and these effects decrease rapidly over time. The positive external effect of redevelopment on residential property prices goes to zero within 4 years on average. While we cannot fully address all potential concerns (e.g., endogeneity concerns of the location and timing of redevelopment), we propose several sensitivity analyses to check the robustness of our main results. The results of the sensitivity analyses are rather consistent and confirm our main results.

Although our results do not capture all external benefits and costs that shopping centers provide for the neighborhood and society as a whole, our analysis shows that redeveloping shopping centers has clear implications on local housing markets using residential property prices. It suggests that using shopping center redevelopment as a tool to combat neighborhood deprivation should be carefully considered by local policy makers because of our following findings. First, the timing of redevelopment is decided by the shopping center owner. The optimal timing of redevelopment from the perspective of shopping center owners may differ from the perspective of society as a whole. Shopping center owners have incentives to postpone redevelopment. Postponing redevelopment of shopping centers may lead to urban blisters and therefore substantial welfare costs to society in terms of decreasing attractiveness of neighborhoods. This suggests that if local policy makers want to prevent urban blisters caused by shopping centers, they should come up with mechanisms to influence the timing of redevelopment. Second, shopping center redevelopment can be used as a tool to combat neighborhood deprivation as the impact of redevelopment is positively associated with residential property prices. However, these positive effects on residential property prices are rather local and they decrease quickly over time.

Despite the fact that our analysis of the dynamics of the before redevelopment effect illustrate some information about the anticipation effects, we are not making any certain conclusions about the existence of anticipation effects. These place-based investments usually need a long period of time to complete. Therefore, the redevelopment of shopping centers might have anticipation effects on nearby property prices. However, from our data set, we only have information about when the redevelopment project is completed, without any knowledge about the announcement or starting date of the project. Therefore, we are unable to identify the anticipation effects. If there are indeed anticipation effects, this would imply that our key finding, the external price effect after redevelopment, is best interpreted as a conservative lower bound estimate. Another potential issue that might be important is that some properties are within the target area of multiple redeveloped shopping centers. There might exist some bias if a property is treated multiple times. However, we leave this issue, together with the anticipation effects, for future research.

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APPENDIX A: AN EXAMPLE OF REDEVELOPED SHOPPING CENTERS

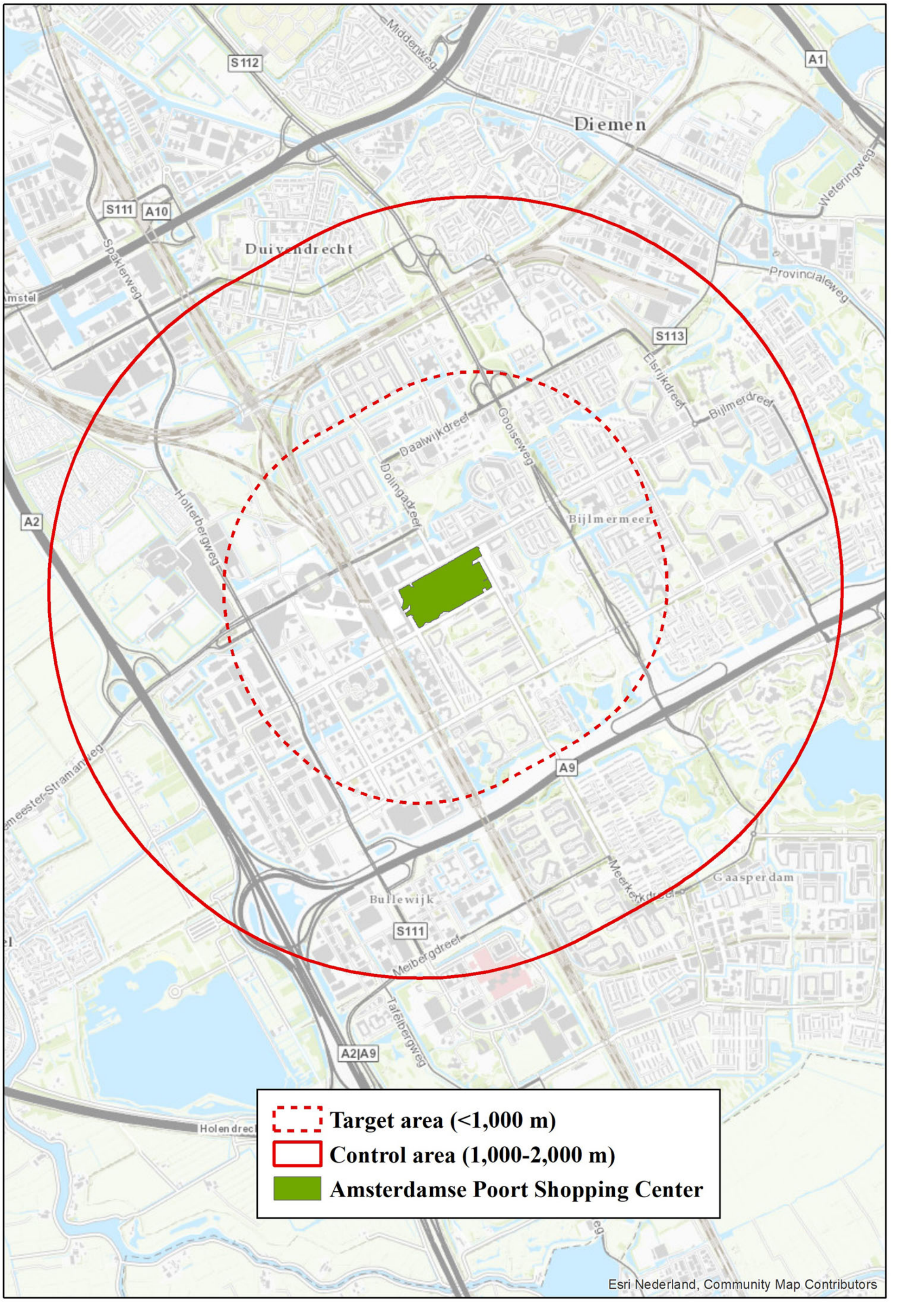

FIGURE A1 Amsterdamse poort shopping center. This is an example of a redeveloped inner-city shopping center used in our paper. As depicted in the figure, we draw polygons for redeveloped shopping centers according to their actual shapes and sizes. This means target areas are not necessarily circular. The distance from a residential property to the nearest redeveloped shopping center is calculated as the shortest distance from that property to the polygon's edge of corresponding shopping center [Color figure can be viewed at wileyonlinelibrary.com]

APPENDIX B: NONRANDOM SELECTION OF REDEVELOPMENT

As depicted in Section 3, the nonrandom selection of redeveloped shopping centers is one of our major concerns. Those shopping centers that got redeveloped may not be chosen randomly but affected by neighborhood characteristics. We are mostly concerned that the decision to redevelop may be affected by nearby property prices. It may be that shopping center owners are more inclined to redevelop their shopping center if the surrounding neighborhood's attractiveness is increasing. We test for this type of endogeneity by investigating whether neighborhood characteristics have any effect on the probability of a shopping center being redeveloped. For this purpose, we propose a logit model.

We take advantage of all shopping centers in our data set, including redeveloped and unredeveloped ones. We gathered neighborhood characteristics from 1995 to 2010 of all the neighborhoods in which our shopping centers are located. These neighborhood characteristics include population density, the percentage of young people (<25 years old) and elderly people (>65 years old), average income,[22] average propertyhold size, and the percentage of immigrants.[23] Table B1 shows the summary statistics of neighborhoods included in the logit model.

By using the NVM data set, we calculate the 5-year moving average property price of each neighborhood in every year. For example, for a neighborhood in 2004, we take the average of its average property price from 2000 to 2004 as its 5-year moving average property price. By doing this, we can capture the trend of property price in each neighborhood. In this way, we can avoid potential bias, which may be caused by unobserved variables, in our estimation results.

A binary dependent variable—let us call it, redeveloped—is generated, which equals one if a shopping center is redeveloped in the corresponding year and zero otherwise. We include the opening year of the shopping center, year fixed effects and urbanity fixed effects as control variables. The aim of this exercise is to figure out whether the neighborhood characteristics are related to the probability of a shopping center being redeveloped. Table B2 shows the results of the logit models. For column (1), we drop all observations with missing values on the right-hand side. Column (2) shows the results with using interpolation to replace some missing values.[24]

Our key variable here is the 5-year moving average property price. In both columns, this variable has a very small, negative, and insignificant coefficient. Opening year has a negative and strongly significant coefficient for both specifications, which represents that a shopping center opened earlier has a higher probability of being redeveloped.

Table B2 indicates that most neighborhood characteristics are not related to the probability of a shopping center being redeveloped. Especially, the moving average property price has no significant influence. This soothes our concern for nonrandom selection to a large extent. Furthermore, there may still exist omitted neighborhood characteristics that have an influence on the location of redevelopment. But this seems not to be a severe problem since the robustness check in Section 6 shows quite consistent results with our baseline specification.

[22]Neighborhood average income is measured in Dutch guilders before 2000. We transfer them into euros.

[23]After 2004, in the Statistics Netherlands neighborhood data set, the percentage of immigrants is divided into two parts-western immigrants and non-western immigrants. We add them up to make sure it consistent with earlier years.

[24]We apply interpolation to every right-hand side variable on year for missing values in these variables. We perform this calculation separately for each shopping center.

TABLE B1 Summary statistics of neighborhoods used in logit regression

	Mean	*SD*	Median	Min	Max
Population density per km^2	4,910.995	2,676.539	4,627	8	24,652
Average household size	2.393	0.551	2.4	0.65	4
Average income per resident (in 1,000 euros)	12.96	4.947	11.39	3.62	44.6
Moving-average property price (in 1,000 euros)	157.748	69.911	146.900	21.124	645.486
Young people (<25 years) (%)	27.426	6.809	28	2	56
Elderly people (>65 years) (%)	17.698	10.108	16	0.5	76
Immigrants (%)	12.683	13.002	8	0.5	87
Opening year	1983	12.723	1982	1885	2010
Redeveloped (1 = yes)	0.018				
Urbanity					
Class 1 (1 = yes)	0.195				
Class 2 (1 = yes)	0.341				
Class 3 (1 = yes)	0.217				
Class 4 (1 = yes)	0.134				
Class 5 (1 = yes)	0.115				
Number of observations	9,463				

TABLE B2 Logit regression results

	(1) **Logit**	**(2)** **Logit**
Moving-average property price (in 1,000 euros)	−1.31e−06 (2.46e−06)	−2.16e−06 (1.76e−06)
Population density per km^2	2.29e−05 (3.54e−05)	−1.85e−06 (2.94e−05)
Young people (<25 years) (%)	−0.00797 (0.0318)	−0.00231 (0.0235)
Elderly people (>65 years) (%)	0.00906 (0.0145)	0.00693 (0.0108)
Average income per resident (in 1,000 euros)	7.63e−05 (0.0717)	0.0395 (0.0467)
Average propertyhold size	0.753 (0.463)	0.430 (0.338)
Immigrants (%)	0.00756 (0.00907)	0.00953 (0.00690)
Opening year	−0.0348*** (0.00573)	−0.0340*** (0.00450)
Constant	63.20*** (11.37)	62.16*** (8.925)
Urbanity fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	9,463	13,905
Pseudo R^2	0.083	0.067

Note: The dependent variable is redeveloped, which equals one if a shopping center is redeveloped in the corresponding year; otherwise zero. Standard errors in parentheses.

*$p < .10$.

**$p < .05$.

***$p < .01$.

APPENDIX C: THE DEVELOPMENT OF RESIDENTIAL PROPERTY PRICES IN TARGET AND CONTROL AREAS

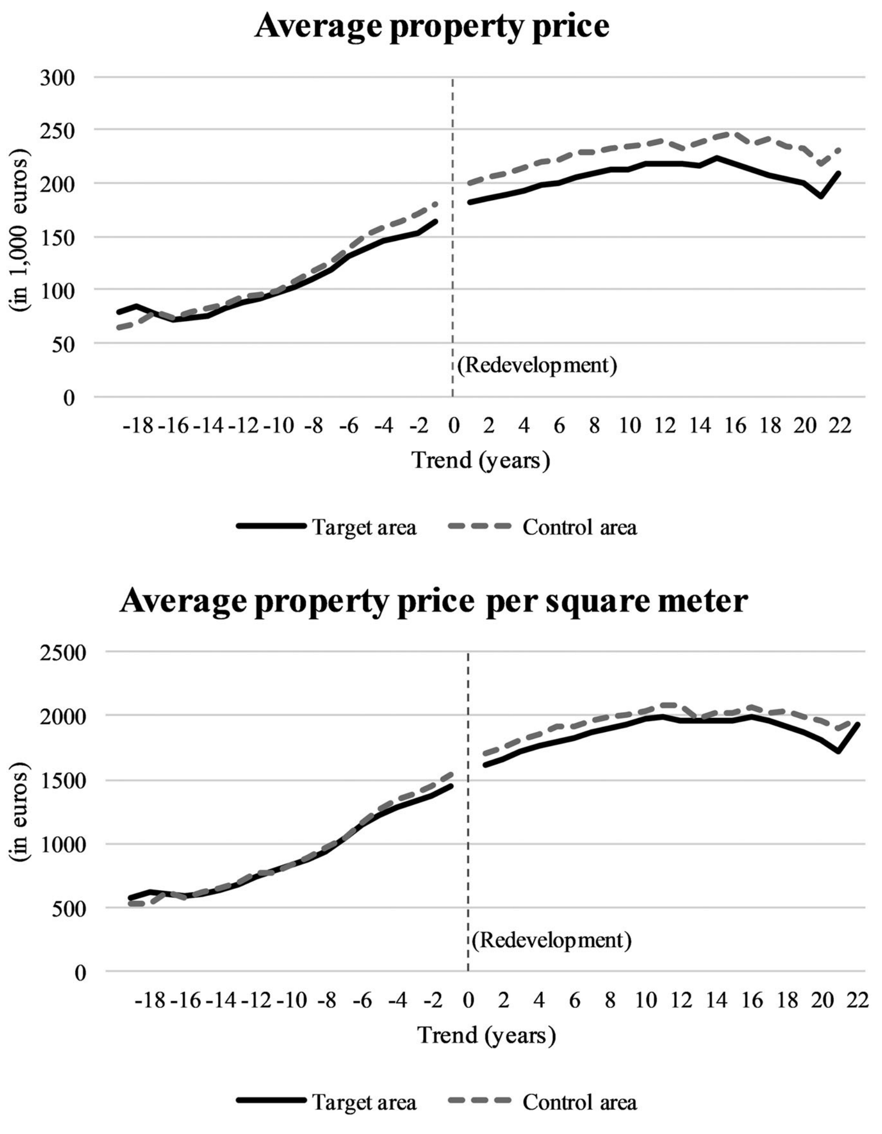

FIGURE C1 The development of average property prices. This figure shows the development of average residential property price (upper panel) and the development of average residential property price per m^2 (lower panel), both in target and control areas. Both average property price and average property price per m^2 are calculated using property prices in our sample. This figure shows that property prices of target and control areas basically follow the same pattern

APPENDIX D: CHANGE OF THE AVERAGE EXTERNAL EFFECTS AFTER REDEVELOPMENT AND CONFIDENCE INTERVALS

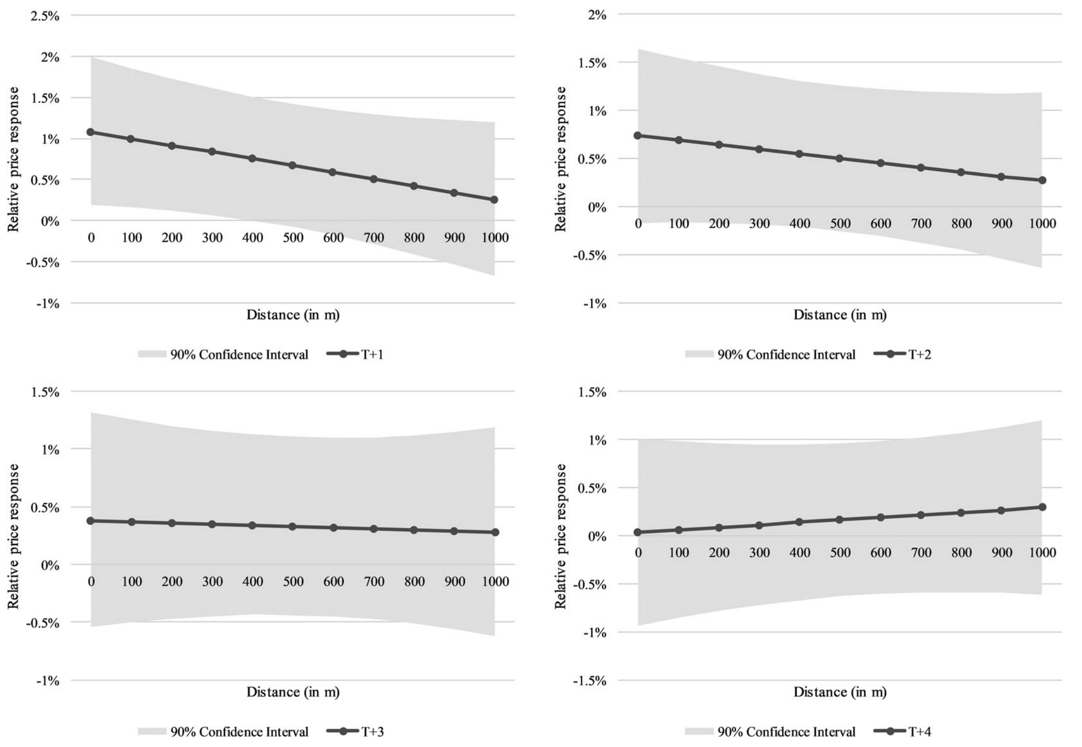

FIGURE D1 Changes of external effects after redevelopment and their confidence intervals. This figure shows the change of the external effects after redevelopment and their confidence intervals. From upper left to lower right panel, it represents 1 year after redevelopment to 4 years after redevelopment separately. Ninety percent significance level is used for confidence intervals